CC® of Retrofitted, Renovated, and Rented Systems and Equipment in Utilities Plants

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KEYWORD

Continuous Commissioning, Functional Performance Testing, Chillers, Boilers, Heating Hot water System

ABSTRACT

It is a common practice for utitlites plants to retrofit machines/equipment and renovate systems during the off-peak seasons or through the year as needed, or rent equipment during peak demand period. It is also quite often that facility owners only specify the desired capacity and leave the rest to the contractor, manufacturer, or rental compnay. Especially for rental machines, due to the assumed temporary nature of their involvement, metering and monitoring instruments are seldom installed, and their operation normally remains a mystery. Significant amount of energy could be wasted and well-planned operation schedule could be interrupted when these equipment do not perform as they are claimed. It is important for Continuous Commissioning® (CC®)[1] engineers to conduct detailed functional performance testing as necessary on any retrofitted, renovated and rented machine or system to achieve a known performance.

This paper summarizes CC measures, procedures and findings of such a process through case studies, including performance testing and evaluation on rental/retrofitted chillers and a renovated heating hot water system.

INTRODUCTION

The Energy Systems Laboratory (ESL) has been conducting CC to the Texas A&M University (TAMU), College Station, Texas over a decade. The CC process was first developed and applied to the air/water sides of building HVAC systems and in recent years, extended to the university's utilities plant systems and central thermal distribution systems [1].

In the past few years, the TAMU physical plant has been conducted several plant expansion, renovation, and retrofit projects to satisfy the increasing chilled water (CHW) and heating hot water (HHW) requirements due to the campus expansion. Rental equipment has also been brought in during the peak cooling and heating months. This paper summarizes CC measures, procedures and findings of such a process through case studies.

CASE 1: WEST CAMPUS I PLANT (WC1) HHW SYSTEM RENOVATION

Site Description

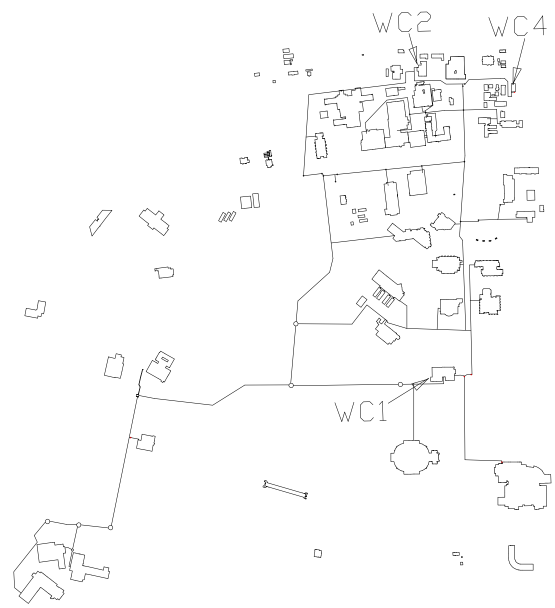

Figure 1 TAMU West Campus HHW Water System

The TAMU west campus has a total of 28 buildings on the central hot water loop with more than 3.5 million square feet of entire conditioned floor area. The west campus heating hot water is supplied by the WC1, the West Campus IV plant (WC4), and the West Campus II plant (WC2). The WC4 plant receives 600-psig steam from the Central Utilities Plant (CUP) on the main campus. The 600-psig steam

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is reduced to 20-psig steam and then sent to three heat exchangers to generate the HHW. The WC2 plant produces the HHW during the peak heating season through a 400-BHP rental gas-to-water boiler.

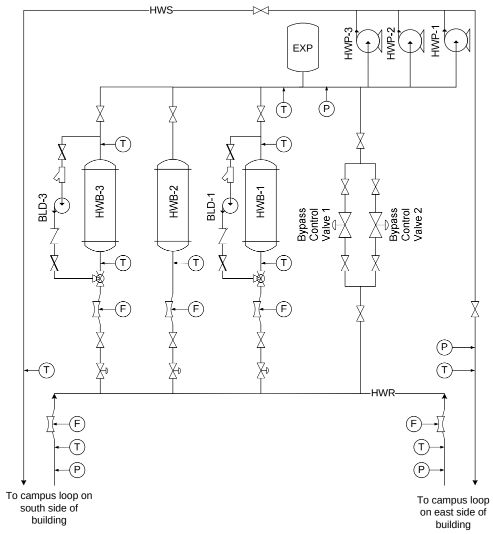

Figure 2 System Diagram of the Renovated WC1 HHW System

The WC1 has just renovated its HHW system with three new 400-BHP gas-to-water boilers to replace the old ones. The renovated HHW system provides engineers opportunities to better implement CC measures (see Figure 2): (1) blender pumps as well as automatic controlled three-way blender valves are installed on the boiler #1 (HWB-1) and boiler #3 (HWB-3). They enable the system to receive low HHW entering temperature while still maintaining a higher boiler entering temperature. (2) Three 100-HP VFD controlled pumps serve the secondary system by maintaining a set point of secondary loop differential pressure, which can be reset based on ambient air temperature. (3) Automatic controlled bypass valves are also installed to be able to achieve an optimized control of the loop supply temperature.

WC1 HHW System Loop Supply Temperature Reset

Continuously high HHW supply temperature (160 °F and above) potentially damages pump seals and control valves and increase heat losses [2]. High HHW supply temperature also results in high heat loss. For example, 5% hot water leakage at 180 °F carries five times more energy into the space than the same amount of water at 90 °F [3]. Since 1998, the temperature reset schedule based on the ambient temperature has been developed and implemented for the TAMU main and west campus HHW systems [4]. At the beginning of the summer of 2005, as a part of the campus wide HHW supply temperature set back action, the renovated WC1 HHW system was required to adjust its HHW supply temperature set-point as well.

The team firstly conducted a simplified start-up commissioning [5] [6] for the renovated WC1 HHW system to verify the boilers' major specifications, proper operation, and control sequences, so that the temperature reset schedule can be implemented without troubles. The design documents, as-built drawings, test data and O&M manuals were collected. The design specification and sequence of the operation and control were reviewed. A site inspection was then conducted. During the entire temperature reset period, because of the low campus HHW load, the WC1 only operated one boiler (HWB-1), which was then shut down and the WC4 took care of the entire west campus by running only one heat exchanger. For the HHW loop supply temperature reset purpose, the simplified start-up commissioning had the following major findings:

- The HWB-1 water entering temperature (135 °F) was lower than the boiler allowed minimum (140 °F) and may cause condensation problem.
- The automatic control sequence for the bypass control valves had been built in. However the bypass line was manually shut, so that the temperature reset was limited by the boiler HHW entering temperature.

Then the CC team and the plant personnel worked together and took the following steps to finally lower the HHW loop supply temperature down to its desired temperature of 120 °F:

1. Resolved the low boiler entering temperature issue by modifying the control program of the three-way blender valve. The three-way blender valve was found to set its open limit at 50% to prevent full circulation. Because of this limit, if further lowering the loop supply temperature, the boiler water entering temperature can not be maintained at a desired level. This setting was then increased to 95% to allow more circulation and to increase the entering temperature to a safe level (145 °F).
2. Tested and manually tuned the newly installed automatic control valves on the bypass line to make sure they move responsively to the control signal.
3. Fully opened the isolation valves on the bypass line. Then manually adjust these two bypass control valves to lower the loop supply temperature from 150 °F to 145 °F

and left this setting for 2 days to see how the system would respond.

4. Systematically fine tuned the PID controls of the bypass control valves and the blender control valve, so that they can coordinate well to smoothly achieve a desired loop supply temperature.

5. The loop supply temperature was then set at 135 °F by automatically adjusting the bypass control valves and the blender valves. This setting was kept for 1-2 days, and the CC team was ready to respond to any complaints from the buildings side.

6. Repeated multi-time of the step 6, reduced 5 °F each step, and finally, the system reached a stable and acceptable temperature of 120 °F.

For the step 6 and 7, it is a campus wide coordinated action that not only WC1 involved, but also WC4 HHW temperature was reset to 120 °F.

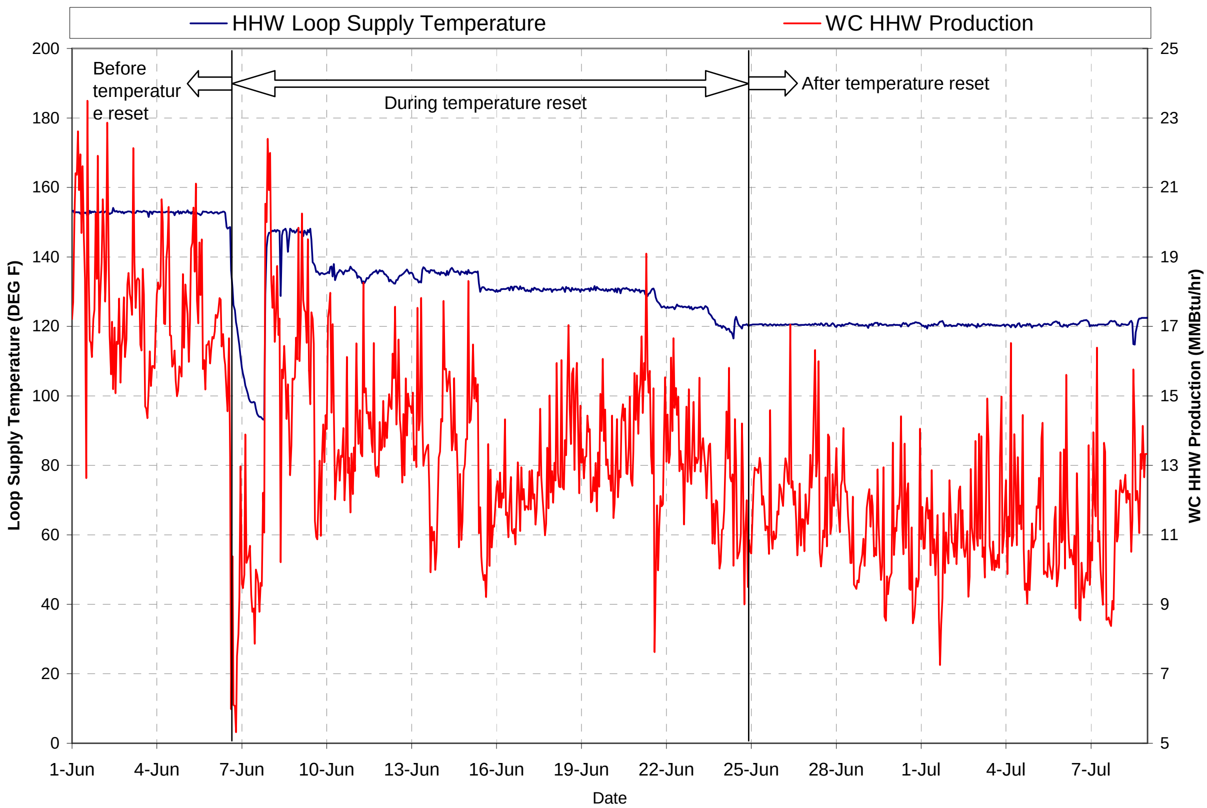

Figure 3 WC HHW Loop Supply Temperature Reset

Figure 3 is a time series plot of the WC HHW production and the loop supply temperature before, during, and after the temperature reset. The HHW production dropped significantly when lowering the loop supply temperature. Figure 4 compares the west campus total HHW consumption among three time periods: (1) 6/1/2004 to 7/13/2004 (gray colored). During this period the campus HHW supply temperature set-point was set at 160 °F; (2) 6/1/2005 to 6/6/2005 (red colored), pre-temperature reset stage, a short period of time when the campus HHW supply temperature was maintained at 153 °F; (3) 6/6/2005 to 7/13/2005, dark blue colored. During this period the campus HHW supply temperature was gradually set back to 120 °F. Due to the similar loop supply temperature set-point, under the same ambient temperature (TOA), the HHW production of period 2 is at the same level of that of period 1. The HHW production of period 3 is significantly lower than that of period 1. By further lowering the HHW supply temperature from 160 °F (set-point of summer, 2004) to 120 °F, 32% of energy is estimated to be saved under the same weather condition. Due to the data availability, the annual HHW savings could not be calculated at this time.

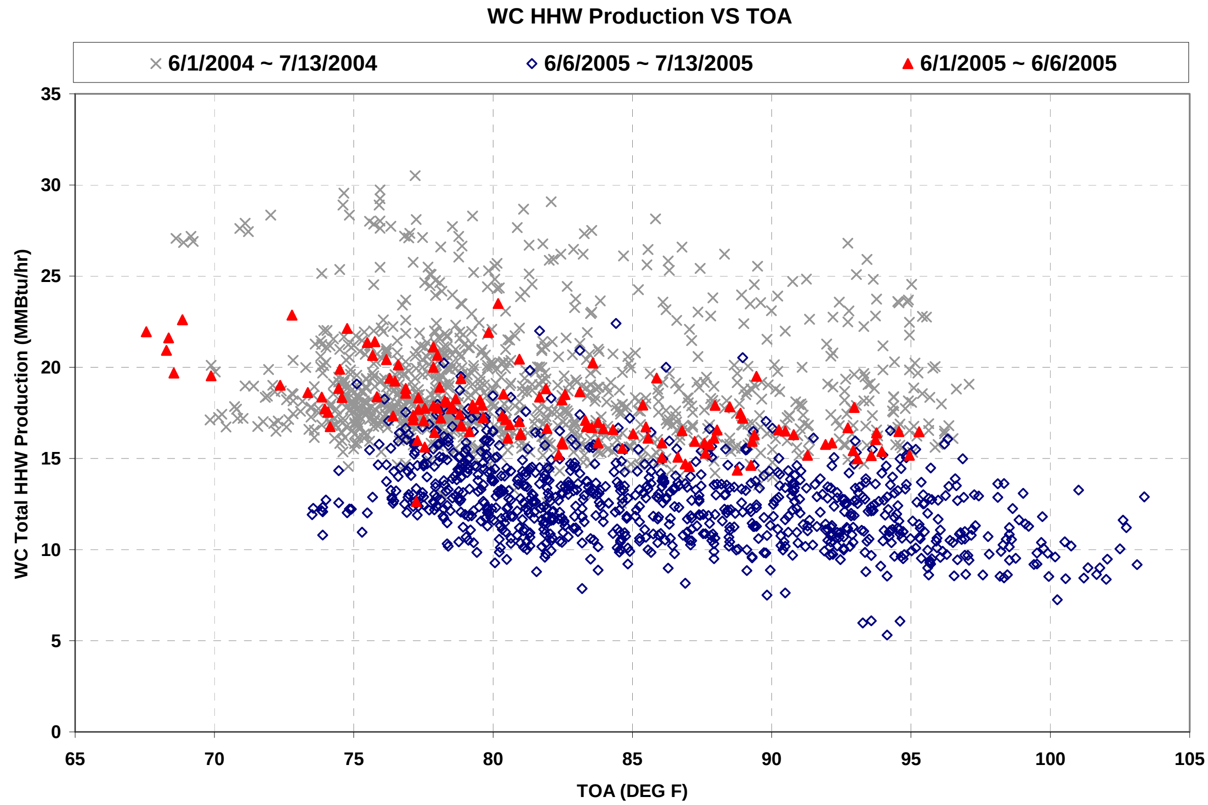

Figure 4 Comparison of the West Campus HHW Production

CASE 2: SOUTH SATTELITE PLANT III (SS3) CHW SYSTEM EXPANSION

Site Description

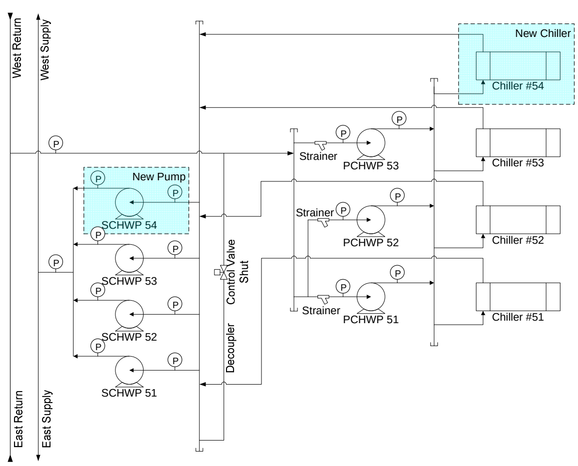

Figure 5 System Diagram of the Expanded SS3 Chilled Water System

The SS3 used to have three electric driven centrifugal chillers with 3,300 tons of total chilling capacity. It is a constant primary/variable secondary system (see Figure 5). Three constant speed pumps (75-HP each) served the primary system. Three VFD pumps (250-HP each) served the secondary system. The primary and secondary system is decoupled by a bypass pipe (decoupler). Currently, as a CC measure, the decoupler is manually closed. All the primary pumps should be off. The VFD controlled secondary pumps are operated to maintain a set-point of loop differential pressure.

In 2004, a new 1470 ton centrifugal chiller (chiller #54) was added to satisfy the increasing cooling requirement due to the campus expansion. Accordingly, a new 250-HP VFD pump was installed in parallel with the existing secondary pumps (see shaded area in Figure 5).

Trouble Shooting the SS3 Pump Operation Problem

After this new chiller was installed, concern regarding to the pump operation was brought out. The plant operators observed very low suction pressure at the secondary pumps and worried about their potential cavitations problem. So they had to turn on the primary pumps to boost up the suction pressure of the secondary pumps.

With the support from the plant personnel, the CC team conducted a field investigation:

- Measured the loop supply and return pressures.
- Measured the suction and discharge pressures for the primary and secondary pumps.
- Measured the chillers chilled water entering and leaving pressures.
- Traced the piping to identify the potential pressure killers, such as the valves, fittings, and etc.

After the collected information was analyzed, we noticed an abnormally high pressure drop between the plant entrance and the suction side of the primary pumps #51 and #53, which were running at that time (see Initial Measurement in Table 1). The PCHWP #52 was off. Its suction pressure is close to the loop entrance pressure. This indicates valves and fittings on the pipes from the loop entrance to the header of the primary pumps inlet did not cause excessive pressure drop. Then, the “Y” strainers installed at the inlet of the PCHWP #51 and #53 were suspected to be blocked.

Table 1 Suction Pressure of the Primary Pumps before and after CC

	Loop Entrance	Primary Pumps		
		#51	#52	#53
Initial Measurement (psig)	53	26.7	*51.5	40.5
Follow up Check (psig)	50	*43	38	*Strainer took off

Note: * means the pump was off.

A plant maintenance person was then called to check these strainers. One strainer was found to be full of debris, which not only caused the excessive pressure drop but also will potentially damage the chiller. For the other strainer, its mesh had been entangled since it was first installed and has lot of debris. During the strainer cleaning process, the CC team did a follow up check (see Initial Measurement in Table 1). At this time, the PCHWP #52 was the only running primary pump and its suction pressure was 38 psig, which means its strainer also needs to be cleaned. After all the strainers were cleaned, the primary pumps were able to be turned off safely. This potential strainer problem had been there for a long time until revealed by the newly installed chiller #54.

CASE 3: CENTRAL UTILITIES PLANT (CUP) RENTAL CHILLERS

Background

The TAMU main campus central CHW system provides space cooling to 111 buildings, which cover more than 9.8 million square feet of dormitories, offices, labs, library, classrooms, and etc. The chilled water is supplied by the CUP and the SS3. The CUP has 21,056 tons of installed chilling capacity and consists of combination of steam/electric driven centrifugal chillers and single/double absorption chillers.

In recent years: (1) several new buildings have been built on main campus, requiring additional cooling capacity for the plants. (2) Natural gas price has increased dramatically. (3) The existing absorption chillers in the CUP deteriorated badly and are planed to remove. The physical plant added a new 1,400 ton electrical chiller in the SS3 in 2004 to satisfy the increased cooling requirement. During the summer months of 2005, in order to satisfy the peak cooling demand, the CUP brought in three electrical driven rental chillers (#A, #B, and #C). The capacity of the rental chiller #A and #C is claimed to be 1,250 tons each. The capacity for rental chiller #B is claimed to be 1,000 tons.

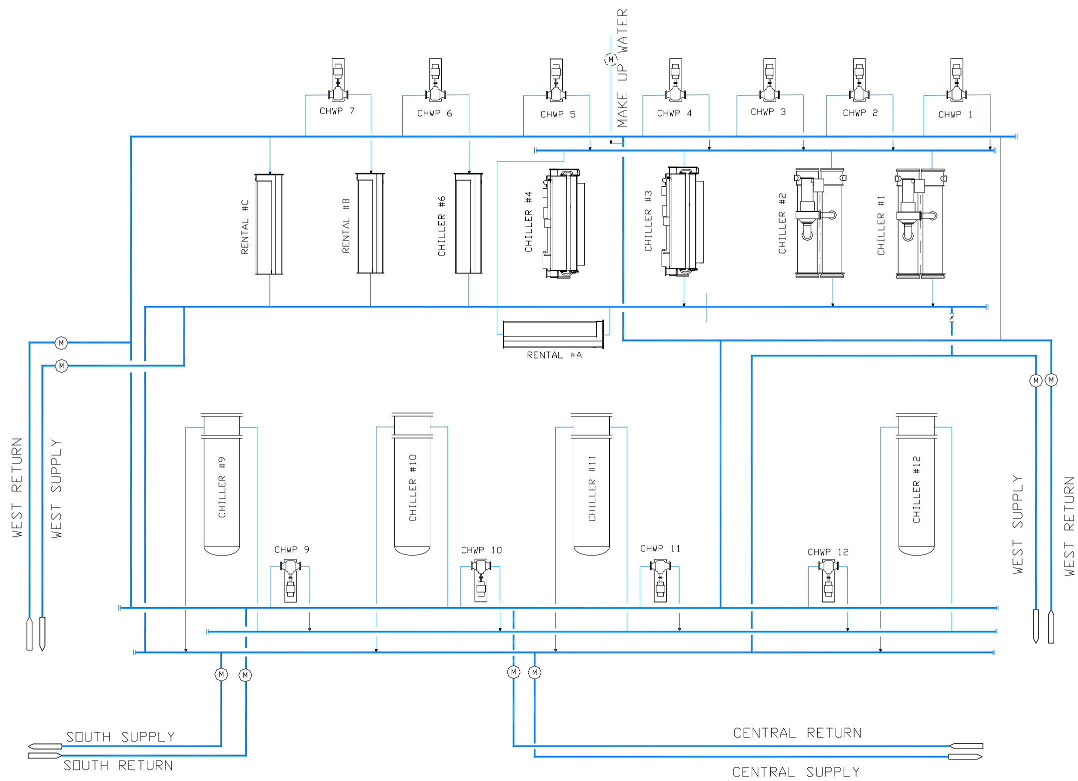

Figure 6 CUP Rental Chillers Arrangement

Figure 6 illustrates the schematic layout of the equipment location and piping connection of the CUP chilled water system. The rental chiller #B and #C are installed on two spare lots beside the chiller #6, the absorber to be removed. They directly connected to the supply/return common header. The rental chiller #A, connecting to the existing piping, instruments and control devices of the chiller #4, is located on the hallway beside the chiller #4, which is the other absorber to be removed.

Rental Chillers Performance Test

Since the total capacity of the rental chillers consists almost 20% of the main campus peak cooling demand, and they will be operated during the peak load period, the actual performance of the rental chillers becomes important to the operation of the chilled water system. However, due to the assumed temporary nature of the rental chillers involvement, metering and monitoring instruments are seldom installed and chiller operation normally remains a mystery. Onsite testing of the rental chillers performance becomes necessary and important.

Onsite testing of the rental chiller is not as "free" as conducting a standard chiller performance test, for an example, ARI test, which allows modulating the chiller parameters to obtain its performance data under different working conditions. Satisfying the peak cooling requirement is the high priority for rental chillers and it is inappropriate to modulate the load and the water temperatures up and down during this critical period. The CC engineer will have to find out the actual rental chiller performance based on whatever information can be collected.

Since the lack of firmed cooling capacity, all the three rental chillers had to run during the testing period. Only the total electricity consumption for the rental chillers can be monitored and trended. Matchbook temperature loggers were used to measure the chilled water supply/return temperatures by inserting them into existing thermal wells on rental chiller #B and #C. Ultrasonic flow meters were used to measure their chilled water flow. The rental chiller #A was monitored by the plant WDPF system. All the data were recorded with 1 minute interval.

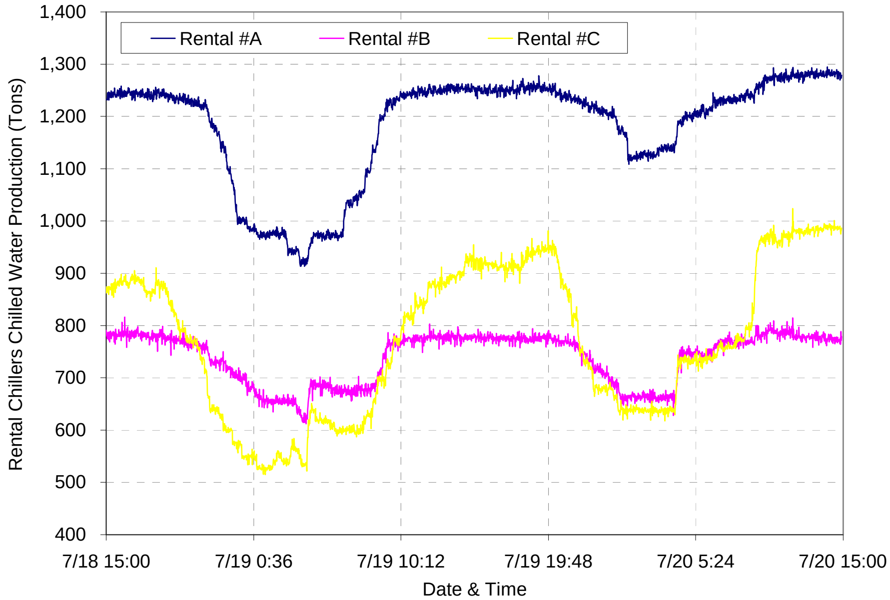

Figure 7 Rental Chiller Trended Productions

Figure 7 is a time series plot of the calculated rental chiller productions. It clearly exhibits that the rental chiller #A can reach its claimed capacity of 1,250 tons. The rental chiller #B is caped at 800 tons and the #C can only reach 1,000 tons. Figure 8 is a time series plot of the trended rental chillers' chilled water entering (CHWET) and leaving (CHWLT) temperatures. Combined the view with Figure 7, it reveals that when the CHWLT can not hold at its set-point (42 °F for all three rental chillers), the chiller will be fully loaded and its production reaches its cap. A spot check was also conducted on the associate condenser water side. The cooling towers had enough capacity to reject the heat. The overall measured kW/Ton for these rental chillers ranges from 0.65 to 0.70, which is higher than their claimed value 0.62.

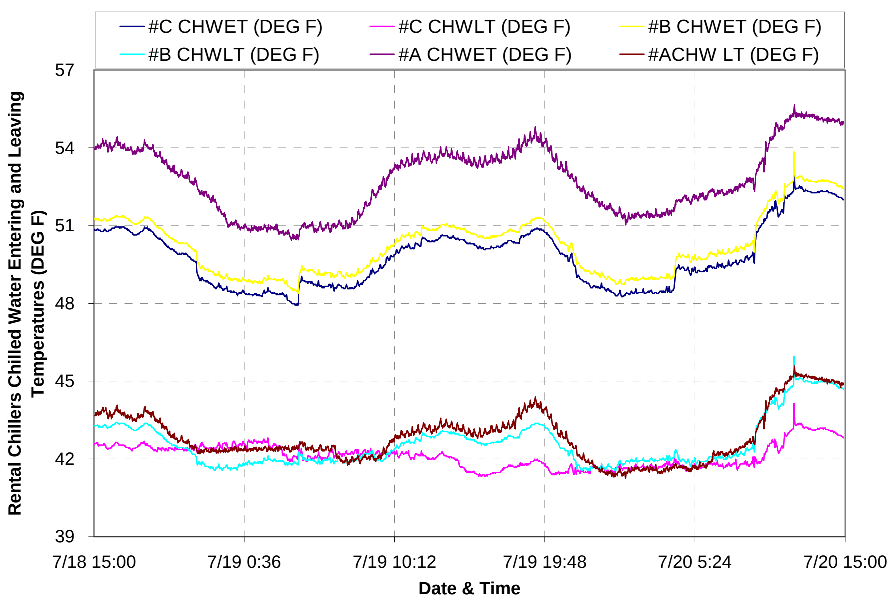

Figure 8 Trended Rental Chillers' Chilled Water Supply and Return Temperatures

The overrated rental chillers indeed caused operation problems to the CUP, especially when another 3,350 ton chiller was out for maintenance. The chilled water loop supply temperature was 5 °F higher than what it should be maintained (42 °F) and may result in complaints.

CONCLUSIONS

When an on going CC process is being implemented into a system, the engineer should pay attention to the renovated/retrofitted sub-systems and rented equipment as well. Detailed functional performance evaluation is necessary on any retrofitted, renovated and rented machine or system to achieve a known performance. This is especially important when it is necessary to coordinate with other processes and serves as an integral part of the overall CC process.

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